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BULLETIN No. 176

# THE USE OF COMMERCIAL FERTILIZERS IN GROWING CARNATIONS

By H. B. DORNER, F. W. MUNCIE, and A. H. NEHRLING

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## Summary of Bulletin No. 176

1. In the carnation experiments reported herein, increasing applications of dried blood in amounts below that causing overfeeding resulted in an increased production of flowers, with a slight decrease in the size of the flowers and the length of their stems. Pages 369, 372-73

2. Small applications of acid phosphate produced no consistent results. Pages 370-71

3. No increase in number or size of flowers was observed from applications of potassium sulfate. Pages 371-72

4. Carnation plants produced as large a number of flowers when grown with commercial fertilizers as when grown with natural manure. Page 376

5. The amount of commercial fertilizer needed to produce this number was moderate, and did not force the plants to the point where there was danger of overfeeding. Pages 373-74

6. The size of flower and length of stem obtained by culture with commercial fertilizers was the same as that obtained by culture with natural manure. Page 377

7. Practically the same percentage of strong stemmed flowers was produced by the use of commercial fertilizers as by the use of manure. Page 377

8. The keeping quality of the flowers was not injured by the use of commercial fertilizers, so long as the applications were not excessive. Pages 377-78

9. No relation was found between the source of plant food (i.e., commercial fertilizers or manure) and the percentage of flowers with split calyces. Pages 378-79

10. The time of maximum crop production was not dependent upon the kind of fertilizer (whether commercial or manure), nor upon the time of its application. Pages 379-80

11. Ammonium sulfate in proper amounts was used in place of dried blood with equally satisfactory results. Pages 380, 82

12. Relatively large quantities of acid phosphate, with a moderate application of dried blood, instead of ruining the plants, increased the number and quality of the flowers. Pages 382, 84

13. Injury from overfeeding resulted from the excessive use of potassium sulfate and of dried blood. Pages 384-86

14. Conclusions. Page 386

# THE USE OF COMMERCIAL FERTILIZERS IN GROWING CARNATIONS

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## INTRODUCTION

The investigation of the use of commercial fertilizers in growing carnations was undertaken by the Illinois Agricultural Experiment Station with a view to determining the feasibility of the complete or partial substitution of them for manure as a source of plant food in producing this important floricultural crop. Commercial fertilizers possess certain advantages over farmyard manure. Chief among these are the definiteness with which the plant-food content and its solubility may be known, and the ease and cheapness of their application as compared with the more bulky manure. Some disadvantages in the use of commercial fertilizers are: the lack of a large proportion of organic matter, which is a part of natural manure and which often is needful to make heavy soils lighter and sandy soils heavier; the danger of overfeeding in an attempt to produce extraordinarily large crops by over-application of such concentrated fertilizers; and the toxicity of some fertilizing materials. These undesirable features bring out the necessity for careful investigation in advance of the general use of commercial fertilizers by growers.

The increasing difficulty in securing natural manure in sufficient quantity, and especially of good quality, to meet the needs of the florists' establishments which supply the demand of the larger cities, makes the study of this subject an imperative one; and even where manure is obtainable, the possibility of using some one commercial fertilizer as a complement to natural manure opens up an important phase of the subject for investigation. The determining factor in deciding whether commercial fertilizers or natural manure will be used, or whether the former may more successfully be used to supplement the latter, will depend in large part upon the relative cost of the two. If the content of manure be considered as nitrogen 10 pounds, phosphorus 2 pounds, and potassium 8 pounds (the average content of manure), and the value of these elements be calculated at 18 cents per pound for nitrogen, 12 cents for phosphorus (from the market price of acid phosphate), and 6 cents for potassium, a ton of manure contains, on the average, plant food which would cost about $2.50 if pur-

chased in the form of commercial fertilizers.[1] A part of this supply will not become available to the plant during the season in which the soil is left in the benches. Considering this factor and adding the possible value of the organic matter present, it seems probable that if good farm manure cannot be purchased for less than the figure given above, it will pay to use commercial fertilizers wholly for the purpose of supplying the plant food. The cost of labor will have an important bearing on the use of the one or the other, the advantage in this regard lying with commercial fertilizers, which are less bulky and need to be applied less often.

The first effort in the experimental work at the University of Illinois has been to determine the amounts of commercial fertilizers that can be applied without danger of overfeeding, and to compare the number and quality of flowers produced by culture with these fertilizers and with natural manure. In addition to results upon these points, a partial report is made upon the kind of fertilizer most profitable to use looking forward to the determination of the best formula.

## GENERAL PLAN OF EXPERIMENTS

In the first experiment, extending over three years, commercial fertilizers in various proportions and amounts were applied to different sections of benches in the greenhouse and the effects on the number and quality of the flowers noted. In the second experiment, extending over two years, the production of sections treated with manure was compared with that from sections treated with commercial fertilizers. The following points were noted in taking the records.

1. Number of flowers
2. Condition of the calyx
3. Size of the flower
4. Length of the stem
5. Stem strength (1911-13 only)
6. Condition of the flower

The data gathered upon the last point included records of those flowers which went to sleep upon the plants, whose petals were crinkled, which opened only partially, whose color was darker or lighter than normal, whose petals were streaked with darker or lighter colors, etc. No one of these conditions, a record of which might have been valuable in case of a widespread occurrence, was general enough to allow a conclusion to be drawn.

### SELECTION AND PREPARATION OF THE SOIL

The soil used in the experimental work described herein was of the type (brown silt loam) common in the part of the state in which the Experiment Station is located. It is believed, however, that the results obtained will be found applicable to any soil upon which carna-

[1]The plant-food content given here is based on a proportion of water approximating 75 percent. Prepared manure often contains considerably less. Its value as a source of plant food, however, may be calculated by the same method as above, provided a guaranteed analysis is obtained from the manufacturer.

tions can be grown satisfactorily by the use of manure, provided the proper physical condition of the soil is first obtained by the application of lime and manure in such amounts as are needful for this purpose.

*Selection in the Field.*—The soil was a well-drained brown silt loam of the type containing the following elements in the approximate amounts indicated:[1]

| | | | |
|---|---|---|---|
| 5000 lbs. | nitrogen | } | per acre of surface soil (2,000,000 lbs.) |
| 1200 " | phosphorus | | |
| 36000 " | potassium | | |

It had been planted to corn the year previous to its use in this experiment. Each year a portion of the field 20 by 100 feet was laid off into plots measuring 4 by 5 feet. Each wagon-load of soil brought in was obtained by taking the same number of shovelfuls of soil from each plot. Enough soil to fill the benches was hauled in and dumped upon a smooth, bare patch of ground. The whole pile was then turned twice and any lumps were carefully broken. This soil formed the basis upon which the experiment was conducted.

*Treatment in the House.*—The soil was brought into the house and the benches (5 inches deep) were filled. After this a straight edge was run over the top of the bench in order to get as nearly as possible the same amount of soil thruout the bench. A weighed amount of manure was spread over the surface, followed by the commercial fertilizers, if any were to be applied. These were turned under, hand trowels being used for the purpose, and the soil was tramped down into the bench again and leveled with a straight edge. In case the soil was unusually loose, enough was added to level it up to the top of the bench. It was then drenched with water and allowed to stand a day or two before the plants were set. The date of setting was about August 5.

## EXPERIMENT WITH VARYING QUANTITIES OF COMMERCIAL FERTILIZERS

During the three years 1909-12, an experiment was carried on with the view of determining the effect of (1) dried blood, (2) acid phosphate, and (3) potassium sulfate[2] in combinations of various proportions. In addition, a comparison was made between sulfate of ammonia and dried blood as a source of nitrogen, and between acid phosphate and rock phosphate as a source of phosphorus. During the year 1909-10, 2,088 plants were grown, producing during the seven months during which records were taken (October to April inclusive) 33,597 flowers; in 1910-11, 2,088 plants were grown, producing 30,547 flowers; and in 1911-12, 1,392 plants, producing 17,846 flowers. The extent of the experiment may be judged from the total number of plants, 5,568, which produced 81,990 flowers.

[1] Cyril G. Hopkins, Soil Fertility and Permanent Agriculture, page 82.

[2] Potassium sulfate is also known as sulfate of potash, and ammonium sulfate as sulfate of ammonia.

During the first two years of the experiment, the varieties Beacon, Enchantress, and White Perfection were grown; during the third year White Perfection was omitted.

Two houses, each 28 by 105 feet, were used in this experiment. Each contained 1,600 square feet of bench space capable of holding 1,600 plants set 1 foot apart each way. Each bench was divided into sections 6 feet long, and on each section a different proportion of the three fertilizers was used. The experiment was repeated with each variety.

For convenience in making comparisons, the various treatments are grouped into sets of three sections each in the following tabular statement. It should be kept in mind that thruout this bulletin the amounts of fertilizer are stated in terms of pounds *per 100 square feet of bench space.* In this experiment each section consisted of 24 square feet of bench space and contained 24 plants.

| | Sec. 1 | Sec. 2 | Sec. 3 |
|---|---|---|---|
| Dried blood | 4 lbs. | 8 lbs. | 16 lbs. |

Acid phosphate and potassium sulfate, 1 lb. (per 100 sq. ft.) in each section.

| | Sec. 7 | Sec. 5 | Sec. 6 |
|---|---|---|---|
| Acid phosphate | 1 lb. | 2 lbs. | 4 lbs. |

Dried blood and potassium sulfate, 4 lbs. and 1 lb. (per 100 sq. ft.) respectively in each section.

| | Sec. 7 | Sec. 8 | Sec. 9 |
|---|---|---|---|
| Potassium sulfate | 1 lb. | 2 lbs. | 4 lbs. |

Dried blood and acid phosphate, 4 lbs. and 1 lb. (per 100 sq. ft.) respectively in each section.

| | Sec. 13 | Sec. 11 | Sec. 12 |
|---|---|---|---|
| Dried blood | 4 lbs. | 8 lbs. | 16 lbs. |
| Acid phosphate | 1 lb. | 2 lbs. | 4 lbs. |

Potassium sulfate, 1 lb. (per 100 sq. ft.) in each section.

| | Sec. 13 | Sec. 14 | Sec. 15 |
|---|---|---|---|
| Dried blood | 4 lbs. | 8 lbs. | 16 lbs. |
| Potassium sulfate | 1 lb. | 2 lbs. | 4 lbs. |

Acid phosphate, 1 lb. (per 100 sq. ft.) in each section.

| | Sec. 19 | Sec. 17 | Sec. 18 |
|---|---|---|---|
| Acid phosphate | 1 lb. | 2 lbs. | 4 lbs. |
| Potassium sulfate | 1 lb. | 2 lbs. | 4 lbs. |

Dried blood, 4 lbs. (per 100 sq. ft.) in each section.

| | Sec. 19 | Sec. 20 | Sec. 21 |
|---|---|---|---|
| Dried blood | 4 lbs. | 8 lbs. | 16 lbs. |
| Acid phosphate | 1 lb. | 2 lbs. | 4 lbs. |
| Potassium sulfate | 1 lb. | 2 lbs. | 4 lbs. |

The treatment given these sections, as regards the method of selecting and preparing the soil, and the application of manure and of commercial fertilizers, has been described on pages 366 and 367. By increasing the amount of one, two, or three of the commercial fertilizers and leaving the amounts of the remaining ones constant, it

was possible to study the effect of the different constituents and determine the one most needed. If dried blood is the fertilizer most needed in the soil and for that reason the growth of the plants is limited, an increase in the amount of dried blood should cause a consistent increase in the flower production. Similarly, if acid phosphate is the fertilizer most needed, an increase should be noted in response to increasing amounts of acid phosphate, or the same result with potassium sulfate would indicate a deficiency of potash in the soil. This, at least, would offer a simple explanation of a consistent increase in the number of flowers or an improvement in their quality. But whatever the explanation, an application of fertilizer yielding returns enough larger to pay for its cost and the labor involved in applying it, with a good percentage of profit, is a good investment.

Only the average results for all the varieties grown are considered in the discussion of this experiment, involving, as it does, a study of the response of carnations to different kinds of fertilizers. It may be stated at this point, however, that in general the results of each variety followed the general averages given. Beacon seemed to show the most erratic tendency in production, while White Perfection seemed least responsive to applications of fertilizer and Enchantress most responsive. In the second experiment (page 373) where a comparison of culture methods is made, a separate report is given for each variety. In that set of data is again seen the small responsiveness of White Perfection as compared with that of White Enchantress.

## VARIATION OF AMOUNT OF DRIED BLOOD

The results from Sections 1, 2, and 3, in which the amount of dried blood was successively increased from 4 to 8 to 16 pounds, are given in Table 1.

TABLE 1.—EFFECT OF INCREASING AMOUNTS OF DRIED BLOOD ON NUMBER AND QUALITY OF FLOWERS

(Average for three years)

| Section | Dried blood | Flowers | Perfect | | Size | Length of stem | Firsts | |
|---|---|---|---|---|---|---|---|---|
| | *lbs.* | *No.* | *No.* | *percent* | *inches* | *inches* | *No.* | *percent* |
| 1 | 4 | 354.7 | 291.0 | 82.1 | 3.06 | 16.02 | 249 | 74.2 |
| 2 | 8 | 368.8 | 306.8 | 83.2 | 3.05 | 15.81 | 277 | 81.8 |
| 3 | 16 | 372.3 | 316.9 | 85.1 | 3.00 | 15.74 | 297 | 83.9 |

The term "perfect" used above refers to those flowers whose calyces were perfect (the remaining number or percentage being "splits"), while the term "firsts" refers to those flowers the strength of whose stems was normal.

Using the letter "I" to indicate a consistent increase in the character considered, "D" a decrease, and "?" to indicate that the results

did not show consistently an increase or a decrease, the results may be summarized as follows:

| | |
|---|---|
| Number of flowers | I |
| Number of flowers with perfect calyces | I |
| Percentage of flowers with perfect calyces | I |
| Number of firsts (stem strength) | I |
| Percentage of firsts (stem strength) | I |
| Size of flower | D |
| Length of stem | D |

The significance of these results lies in the fact that an increase from 4 to 16 pounds in the amount of dried blood applied, caused the number of flowers produced to increase, and the size of the flower and the length of the stem to decrease. These figures are the average for eight sets of sections, each section containing 24 plants. Hence the increase was nearly one flower per plant. In a house containing 1,600 plants, the net increase would amount to 1,200 flowers, an increase worthy of consideration. On the other hand, it is doubtful if a decrease of six-hundredths of an inch in width of flower, or of one-quarter of an inch in length of stem, would be at all noticeable unless careful records were kept.

Without using these data as evidence that the extent to which dried blood is applied to carnations has any effect on the splitting of the flowers, it should be pointed out here that both the number and the percentage of flowers with perfect calyces increased with increasing applications of dried blood. It is hardly reasonable to believe, then, that the use of dried blood induces splitting. Further evidence that a moderate fertilization with chemicals does not induce splitting is presented on pages 378-79.

## Variation of Amount of Acid Phosphate

The results from the three sections in which the amount of acid phosphate only was increased (from 1 to 2 to 4 pounds) were as shown in Table 2.

Table 2.—Effect of Increasing Amounts of Acid Phosphate on Number and Quality of Flowers

(Average for three years)

| Section | Acid phosphate | Flowers | Perfect | | Size | Length of stem | Firsts | |
|---|---|---|---|---|---|---|---|---|
| | *lbs.* | *No.* | *No.* | *percent* | *inches* | *inches* | *No.* | *percent* |
| 7 | 1 | 367.8 | 286.6 | 77.9 | 3.10 | 16.03 | 334.5 | 90.3 |
| 5 | 2 | 357.5 | 282.1 | 78.9 | 3.09 | 15.83 | 308.0 | 89.2 |
| 6 | 4 | 368.3 | 298.7 | 81.1 | 3.06 | 16.18 | 310.0 | 88.4 |

Using the letters indicated on the preceding page, the results may be summarized as follows:

| | |
|---|---|
| Number of flowers | ? |
| Number of flowers with perfect calyces | ? |
| Percentage of flowers with perfect calyces | I |
| Number of firsts | ? |
| Percentage of firsts | D |
| Size of flower | D |
| Length of stem | ? |

It will be seen that the results as a whole were not consistent, and no conclusion in regard to the value of acid phosphate can be drawn from them. In each section the same small amount of dried blood (4 pounds) was used. Since dried blood when increased did produce a consistent increase or decrease in each of the points tabulated above, and probably was the factor which limited the production of the flowers, it is not surprising that increasing amounts of acid phosphate applied in connection with only small amounts of dried blood failed to show concordant results. What effect increasing amounts of acid phosphate would have when used in connection with ample quantities of dried blood is a different problem, requiring further investigation.

## VARIATION OF AMOUNT OF POTASSIUM SULFATE

The three sections in which the amount of potassium sulfate only was increased, while the amounts of dried blood and acid phosphate were kept constant, gave the following results:

TABLE 3.—EFFECT OF INCREASING AMOUNTS OF POTASSIUM SULFATE ON NUMBER AND QUALITY OF FLOWERS

(Average for three years)

| Section | Potassium sulfate | Flowers | Perfect | | Size | Length of stem | Firsts | |
|---|---|---|---|---|---|---|---|---|
| | *lbs.* | *No.* | *No.* | *percent* | *inches* | *inches* | *No.* | *percent* |
| 7 | 1 | 367.8 | 286.6 | 77.9 | 3.10 | 16.03 | 334.5 | 90.3 |
| 8 | 2 | 367.5 | 295.2 | 80.3 | 3.07 | 16.02 | 315.0 | 92.7 |
| 9 | 4 | 363.1 | 296.9 | 81.7 | 3.05 | 15.99 | 336.0 | 94.5 |

| | |
|---|---|
| Number of flowers | D |
| Number of flowers with perfect calyces | I |
| Percentage of flowers with perfect calyces | I |
| Number of firsts (stem strength) | ? |
| Percentage of firsts (stem strength) | I |
| Size of flower | D |
| Length of stem | D |

For the same reason as that given in the discussion of the results with acid phosphate, the results here would not be expected to be of

the same value as they would if a larger amount of dried blood had been used. What the effect would be in that case can only be determined by further experiment; these results, therefore, do not prove conclusively that the addition of potassium sulfate decreases the number of flowers produced.

## THE IMPORTANCE OF DRIED BLOOD

The paramount importance of dried blood is shown in the following combinations of commercial fertilizers by an increase in the number of flowers with an increase in the amount of dried blood, whether or not the amounts of the other fertilizers were also increased.

| | | No. of flowers |
|---|---|---|
| | *Dried blood only, increased* | |
| Sec. 1. | 4 lbs. dried blood | 354.7 |
| Sec. 3. | 16 lbs. dried blood | 372.3 |
| | *Dried blood and acid phosphate increased* | |
| Sec. 13. | 4 lbs. dried blood<br>1 lb. acid phosphate | 361.2 |
| Sec. 12. | 16 lbs. dried blood<br>4 lbs. acid phosphate | 377.1 |
| | *Dried blood and potassium sulfate increased* | |
| Sec. 13. | 4 lbs. dried blood<br>1 lb. potassium sulfate | 361.2 |
| Sec. 15. | 16 lbs. dried blood<br>4 lbs. potassium sulfate | 379.1 |
| | *Dried blood, acid phosphate, and potassium sulfate increased* | |
| Sec. 19. | 4 lbs. dried blood<br>1 lb. acid phosphate<br>1 lb. potassium sulfate | 352.8 |
| Sec. 21. | 16 lbs. dried blood<br>4 lbs. acid phosphate<br>4 lbs. potassium sulfate | 364.6 |

Among these sections, the three producing the largest number of flowers ranked as follows:

| | | | No. of flowers |
|---|---|---|---|
| First: | Sec. 15. | *Dried blood*.....*16 lbs.*<br>Acid phosphate ..... 1 lb.<br>Potassium sulfate ..... 4 lbs. | 379.1 |
| Second: | Sec. 12. | *Dried blood*.....*16 lbs.*<br>Acid phosphate ..... 4 lbs.<br>Potassium sulfate ..... 1 lb. | 377.1 |
| Third: | Sec. 3. | *Dried blood*.....*16 lbs.*<br>Acid phosphate ..... 1 lb.<br>Potassium sulfate ..... 1 lb. | 372.3 |

Section 21, having a treatment of dried blood 16 pounds, acid phosphate 4 pounds, and potassium sulfate 4 pounds, gave a somewhat lower average of 364.6 flowers per season. This, however, is

considerably higher than the average of the adjoining check section with which, because of the sameness of greenhouse conditions, it is most fairly compared.

The average size of the flowers from the four sections in which a heavy fertilization with dried blood was common to all is shown in the following tabulation. For the purpose of comparison there is also given the average size of the flowers produced on all the fertilized sections and of those produced on the four unfertilized sections.

| | | Average size of flower, *inches* |
|---|---|---|
| Sec. 3. | *Dried blood* ..... *16 lbs.* | |
| | Acid phosphate ..... 1 lb. | |
| | Potassium sulfate ..... 1 lb. | 3.00 |
| Sec. 21. | *Dried blood* ..... *16 lbs.* | |
| | Acid phosphate ..... 4 lbs. | |
| | Potassium sulfate ..... 4 lbs. | 3.02 |
| Sec. 15. | *Dried blood* ..... *16 lbs.* | |
| | Acid phosphate ..... 1 lb. | |
| | Potassium sulfate ..... 4 lbs. | 3.02 |
| Sec. 12. | *Dried blood* ..... *16 lbs.* | |
| | Acid phosphate ..... 4 lbs. | |
| | Potassium sulfate ..... 1 lb. | 3.05 |
| All fertilized sections ..... | | 3.05 |
| Unfertilized sections ..... | | 3.06 |

It is evident that the use of a large amount of dried blood was the factor concerned in the production of smaller flowers. It seems that dried blood, up to the limit where overfeeding sets in, causes the number of flowers to increase and the average size of the individual flowers slightly to decrease.

In connection with this discussion it is well to draw a comparison between the average results obtained from all the fertilized sections and those obtained from four sections which received no treatment other than an initial application of 125 pounds of well-rotted manure per 100 square feet. The results are given below.

TABLE 4.—NUMBER AND QUALITY OF FLOWERS FROM FERTILIZED AND FROM UNFERTILIZED SECTIONS

(Average for three years)

| Number of sections | Flowers per section | Perfect | | Size | Length of stem | Firsts | |
|---|---|---|---|---|---|---|---|
| | *No.* | *No.* | *percent* | *inches* | *inches* | *No.* | *percent* |
| Four unfertilized..... | 308.8 | 226.0 | 73.2 | 3.06 | 15.06 | 283.2 | 88.2 |
| Eighteen fertilized... | 364.1 | 302.5 | 83.1 | 3.05 | 15.03 | 298.1 | 86.1 |

## COMPARISON OF COMMERCIAL FERTILIZERS AND MANURE

Pending further investigation into the value of acid phosphate and potassium sulfate used in connection with ample amounts of dried

blood (or some other fertilizer which supplies nitrogen), it was thought advisable to test the value of commercial fertilizers in carnation culture by a comparison with natural manure. For this purpose 8 pounds of dried blood per year per 100 square feet of bench space was chosen as representing a *moderate* application on the brown silt loam soil used at the Experiment Station, and therefore probably a safe one on any soil in the state. Two pounds each of acid phosphate and potassium sulfate were used tentatively, altho investigation has not yet shown the best amount of either to use, nor even the necessity for using either.

In this experiment 1,056 plants, occupying as many square feet of bench space, were used, two benches being planted with White Enchantress and two with White Perfection. Each bench was divided into two sections, and the treatments arranged in such a way as would tend to equalize the effects of unequal temperature and illumination. The following diagram indicates the arrangement of sections in the benches used for either variety. Each section measured 4 by 33 feet

| | |
|---|---|
| Commercial Fertilizer | Manure |
| Manure | Commercial Fertilizer |

and contained 132 plants. Hence, of each variety, 264 plants were used for culture with manure and the same number for culture with commercial fertilizers, a total of 528 plants under each culture method.

## Fertilization of the Sections

A preliminary experiment was run during the season October, 1910, to May, 1911, inclusive, with White Enchantress. At the end of the season, the number of flowers produced by the two treatments was as follows:

| | |
|---|---|
| Culture with manure: | |
| Flowers per 264 plants | 3889 |
| Flowers per plant | 14.7 |
| Culture with commercial fertilizers: | |
| Flowers per 264 plants | 4084 |
| Flowers per plant | 15.4 |

In this experiment the culture with the manure was as follows:

(1) An application of 250 pounds of well-rotted manure per 100 square feet was made before the plants were set in.

(2) Liquid cow manure (made as described on page 375) was applied at the rate of 8 gallons per 100 square feet, on the following dates: December 21, January 11, February 18, March 13, March 27, April 4, and April 24.

(3) Mulches of sheep manure, at the rate of about 12 pounds per 100 square feet, were applied on January 17 and March 2.

The results showed a clear advantage in favor of culture with commercial fertilizers.

In 1911-12 and the following year, the applications of cow and

liquid manure, and of sheep manure mulches were increased as described in the next paragraphs.

*Manure Treatment.*—The sections under culture with manure were treated with an initial application of well-rotted manure (containing 44.4 percent moisture) as follows:

| | |
|---|---|
| Per 100 sq. ft. of bench space | 312.5 lbs. |
| Or per section | 412.5 lbs. |

In addition, these sections received thirteen applications of liquid manure at the following rate:

| | |
|---|---|
| Per 100 sq. ft. of bench space | 13.6 gals. |
| Or per section | 18.0 gals. |

The applications were made on the following dates:[1] November 3, November 25, December 9, 16, 28, January 12, 20, 31, February 17, 24, March 20, April 4 and 16.

This liquid manure was made by allowing ⅔ bushel of fresh cow manure to soak for a day in 50 gallons of water. The supernatant liquid was drawn off and used, after which the barrels were refilled and the contents allowed to ferment for about two weeks before being used.

These sections also received mulches of sheep manure as follows:

| | | | |
|---|---|---|---|
| November 13: | Per 100 sq. ft. of bench space | | 11 lbs. |
| | Or per section | (7473.1 gms.) | 16.5 lbs. |
| December 2: | Same as November 13 | | |
| March 2: | Per 100 sq. ft. of bench space | | 7 lbs. |
| | Or per section | (4906.5 gms.) | 11 lbs. |

*Commercial Fertilizer Treatment.*—The sections under culture with commercial fertilizer received an initial application of manure from the same lot as the preceding sections, as follows:

| | |
|---|---|
| Per 100 sq. ft. of bench space | 125 lbs. |
| Or per section | 165 lbs. |

This was applied for the purpose of keeping the soil mellow and promoting bacterial action.

In addition, these sections received an initial application of commercial fertilizer as follows:

| | | |
|---|---|---|
| Dried blood per 100 sq. ft. of bench space | 2 | lbs. |
| " " per section (1196.8 gms.) | 2.64 | lbs. |
| Acid phosphate per 100 sq. ft. of bench space | 2 | lbs. |
| " " per section (1196.8 gms.) | 2.64 | lbs. |
| Sulfate of potash per 100 sq. ft of bench space | 2 | lbs. |
| " " " per section (1196.8 gms.) | 2.64 | lbs. |

On November 1-2, December 21-22, and February 13-15, further additions of 2 pounds of dried blood per 100 square feet of bench space were made. These four applications constituted the entire treatment, so far as fertilization was concerned, thruout the year.

[1]Both these dates and the dates given for applications of sheep manure and commercial fertilizer are for the year 1911-12. During the second year, 1912-13, the selection and treatment of the soil and the time and amount of applications of manure or commercial fertilizer were duplicated as nearly as possible, the date in no case varying more than three days from that of the previous year.

The dried blood used in this experiment contained 13.66 percent nitrogen; the acid phosphate, 7.03 percent phosphorus; and the sulfate of potassium, 41.96 percent potassium.

### Comparison of Number of Flowers Produced

A comparison of the number of flowers produced during 1911-12 and 1912-13 under the two treatments is shown in Table 5. The flowers were picked every morning (with the exception of Sundays and holidays) and put into water. Records were taken on the afternoon of the same day. It will be noted that in the total production of both varieties for the two years there was a difference of only four flowers between the two treatments.

Table 5.—Number of Flowers from Manure and from Commercial Fertilizer Sections, 1911-13

| Treatment | 1911-12 | 1912-13 | Average 1911-13 |
|---|---|---|---|
| **White Enchantress** | | | |
| Manure: | | | |
| Flowers per 264 plants | 3400 | 4612 | 4006 |
| Flowers per plant | 12.9 | 17.4 | 15.3 |
| Commercial fertilizers: | | | |
| Flowers per 264 plants | 3473 | 4647 | 4060 |
| Flowers per plant | 13.1 | 17.6 | 15.4 |
| **White Perfection** | | | |
| Manure: | | | |
| Flowers per 264 plants | 3730 | 4348 | 4039 |
| Flowers per plant | 14.1 | 16.4 | 15.3 |
| Commercial fertilizers: | | | |
| Flowers per 264 plants | 3778 | 4200 | 3989 |
| Flowers per plant | 14.3 | 15.9 | 15.1 |
| **Both Varieties** | | | |
| Manure: | | | |
| Flowers per 528 plants | 7130 | 8960 | 8045 |
| Flowers per plant | 13.5 | 16.9 | 15.2 |
| Commercial fertilizers: | | | |
| Flowers per 528 plants | 7251 | 8847 | 8049 |
| Flowers per plant | 13.7 | 16.3 | 15.2 |

### Comparison of Quality of Flowers

The data on three of the points noted in the records in regard to the quality of the flowers produced, viz., size of flower, length of stem, and percentage of flowers with normally strong stems are shown in Table 6.

TABLE 6.—QUALITY OF FLOWERS FROM MANURE AND FROM COMMERCIAL FERTILIZER SECTIONS, 1911-13

| Treatment | Size of flower | Length of stem | Strong stems |
|---|---|---|---|
| | White Enchantress | | |
| | *inches* | *inches* | *percent* |
| Manure | 3.22 | 15.42 | 88.6 |
| Commercial fertilizers | 3.22 | 14.88 | 87.5 |
| | White Perfection | | |
| Manure | 3.00 | 15.63 | 84.6 |
| Commercial fertilizers | 2.98 | 15.45 | 84.5 |
| | Both Varieties | | |
| Manure | 3.11 | 15.52 | 86.6 |
| Commercial fertilizers | 3.10 | 15.17 | 86.0 |

With each variety, the size of flower and the percentage of total number with strong stems were practically the same under each treatment. The average length of stem was about ⅓ inch longer under culture with manure. The data in regard to this point, however, are not so accurate as the others, since in breaking a flower a picker might occasionally choose any one of two or three nodes and thereby cause the stem length to vary as much as three inches.

*Effect of Commercial Fertilizers on the Keeping Quality of Flowers*

The statement is made at times that carnations when raised with chemicals do not have a keeping power equal to that of carnations grown with manure. For this reason records were kept of the flowers raised by each method during the years 1911-12 and 1912-13.

On Monday of each week beginning January 13 and ending March 24 (ten weeks), twenty flowers, or thereabouts, were selected from each treatment. Care was taken to secure normally healthy flowers of that day's crop. Only strong-stemmed flowers having no imperfection in the calyx or corolla were chosen. The stems were cut to a uniform length (12 inches), and the flowers placed in tall vases in the flower cellar, which was kept at an average temperature of 50° F. The water was changed daily but the stems were not cut. The figures in Table 7 indicate the average length of time that elapsed before the flowers had wilted or gone to sleep. Records were taken each morning.

TABLE 7.—EFFECT OF MANURE AND OF COMMERCIAL FERTILIZERS ON THE KEEPING QUALITY OF FLOWERS

| Culture | Number of days between picking and wilting | |
|---|---|---|
| | 1911-12 | 1912-13 |
| Manure | 16.30 | 14.30 |
| Commercial fertilizer | 15.97 | 13.70 |
| Difference | .33 | .60 |

In this experiment, where there was no excessive forcing, the keeping power of the flowers was evidently not affected greatly by the source of plant food.

During the year 1909-10 a series of similar experiments was conducted which tested the keeping quality of flowers: (1) when fed with a small amount of manure and no commercial fertilizers, (2) when fed with the same amount of manure and moderate amounts of commercial fertilizers, up to twice those mentioned on page 375, and (3) when fed with four times the amount of one or the other of the fertilizers used in the experiment from which the data above were secured, with the same small amount of manure as in the other experiments. The following results were obtained:

TABLE 8.—EFFECT OF VARIATION OF AMOUNTS OF COMMERCIAL FERTILIZER ON THE KEEPING QUALITY OF FLOWERS

| Application | Number of days between picking and wilting | | | |
|---|---|---|---|---|
| | Nitrogen | Phosphorus | Potassium | Average |
| No chemicals .... | .... | .... | .... | 10.7 |
| Moderate ..... | 10.0 | 9.6 | 9.9 | 9.8 |
| Excessive ..... | 8.5 | 9.5 | 9.3 | 9.1 |

The moderate forcing of the plants led to a slight decrease in their keeping power, which was further reduced by excessive forcing. The decrease was so small, however, that it is hardly necessary to fear this result from the moderate use of commercial fertilizers.

### *Relation of Feeding to Splitting in Carnations*

In order to ascertain whether there was any relation between feeding and splitting in carnations, a record was kept thruout this experiment of the number of split calyces that appeared. The number of flowers with perfect calyces is shown in Table 9.

The agreement in the percentages for the two culture methods is clear enough proof that the tendency to split is not increased by culture with commercial fertilizers. Nor is it decreased. Indeed, the figures offer conclusive evidence that splitting has no relation to the materials from which the food supply is maintained. The series of experiments carried on from 1909 to 1912 with Beacon, Enchantress, and White Perfection varieties (pages 367-73) gave the following results:

(1) Those sections to which only a small amount of manure and no fertilizer was applied, and which produced an abnormally small number of flowers (9.4 per plant for seven months), averaged 73.2 percent with perfect calyces.

(2) Those sections to which was applied only one-half the amount of commercial fertilizer applied in the experiment described on page 375 (and which produced an average of 12.2 flowers per plant for seven months) averaged 81.9 percent perfect calyces.

(3) The average flower production of all the sections to which

fertilizer was applied was 12.6 blossoms per plant for each season of seven months. Of this number 83.1 percent had perfect calyces.

These results indicate that when plants are underfed there is a somewhat greater tendency for the flowers to split.

TABLE 9.—NUMBER OF FLOWERS WITH PERFECT CALYCES PRODUCED WITH MANURE AND WITH COMMERCIAL FERTILIZERS

| Treatment | 1911-12 | 1912-13 | Total |
|---|---|---|---|
| **White Enchantress** | | | |
| Manure | 3150 | 4076 | 7226 |
| Percent of total | 92.6 | 88.4 | 90.5 |
| Commercial fertilizer | 3210 | 4237 | 7447 |
| Percent of total | 92.4 | 91.2 | 91.8 |
| **White Perfection** | | | |
| Manure | 3350 | 3837 | 7187 |
| Percent of total | 89.8 | 88.2 | 89.0 |
| Commercial fertilizer | 3412 | 3734 | 7146 |
| Percent of total | 90.3 | 88.9 | 89.6 |
| **Both Varieties** | | | |
| Manure | 6500 | 7913 | 14413 |
| Percent of total | 91.2 | 88.3 | 89.5 |
| Commercial fertilizer | 6622 | 7971 | 14593 |
| Percent of total | 91.3 | 90.1 | 90.6 |

On the other hand, in the sections where, during 1912-13, large quantities of fertilizer (about 30 pounds, in weekly portions) were applied,—in the case of dried blood and potassium sulfate, sufficient to ruin the majority of flowers produced after February (page 385), —the percentage of flowers with perfect calyces was as follows:

Large amount of dried blood .....91.8 percent perfect
Large amount of sulfate of potassium .....89.1 percent perfect

The flowers grown with moderate amounts of fertilizer averaged 84.3 percent with perfect calyces; those grown with large amounts of acid phosphate, without injury to the flowers, (page 384) averaged 87.9 percent with perfect calyces. These figures are averages for the varieties White Perfection and Enchantress. The number of "splits" in those sections receiving a moderate application of ammonium sulfate was not unusually large.

From a practical standpoint, the fact to be emphasized is that a moderate application of commercial fertilizers will not cause an increase in splitting.

## INFLUENCE OF FERTILIZING ON TIME OF MAXIMUM CROP PRODUCTION

The profit to be realized from the sale of a crop of carnations depends largely on its *seasonableness*. This is illustrated by the weekly

schedule of wholesale prices for the year October 1, 1911, to October 1, 1912. During the season October 21 to February 24, the prices averaged $3 per hundred for flowers rated as "first quality"; during the period March 2 to June 15, the prices averaged $2 per hundred; and from June 15 to October 14, $1 to $1.50 per hundred. This even scale of prices, however, was broken by a sharp rise in price near Thanksgiving, a larger one at Christmas and New Year's season, and another at Easter time. The higher prices at these times are coupled with a larger demand, and the florist who is able to bring his carnations into crop to meet this demand can realize a profit some hundred percent greater than he otherwise could, and with no extra amount of stock. The occasional experience of most growers of having few flowers just before Christmas and New Year's, but an abundance about the middle of January, when prices are 50 percent lower, is an illustration in point. For this reason it is worth while to study the various factors which control the time of maximum crop production.

In order to throw some light on the feasibility of controlling the time of cropping by the application of fertilizers either at a certain time or of a more or less concentrated kind, the results from each of the two different treatments used in this experiment were averaged weekly. Under one treatment, as stated previously, liquid manure or some other fertilizer in dilute form was applied approximately each week; in the other, applications of concentrated fertilizer were made at four periods during the season, and approximately eight weeks apart. Now if the time of application or the concentration of the plant food does markedly affect the time of cropping, the weekly records of the two series should show a marked difference.

In Fig. 1 is shown a graphic representation of the results obtained with White Enchantress. The units on the diagram from left to right represent the weeks of the season September 12 to June 1, 1912-13, during which records were taken, and the height of the line each week represents the production for that week. The solid line represents the results from the sections treated with manure (D-Sections), and the broken one, from those treated with commercial fertilizers (E-Sections). The curves are so nearly identical that it is clear that the time of maximum crop production cannot be varied greatly by the form of plant food used nor by the time of its application.

The curves for White Perfection (Fig. 2) show a more nearly even production than those for White Enchantress. The time between two periods of high production is the same for both varieties, thirteen to fourteen weeks.

## USE OF AMMONIUM SULFATE AND ROCK PHOSPHATE

That ammonium sulfate in proper amounts may be used with as good results as dried blood is evident from the following figures, which show the average production of flowers of the varieties Beacon, Enchantress, and White Perfection during a seven months' season of the years 1909-12.

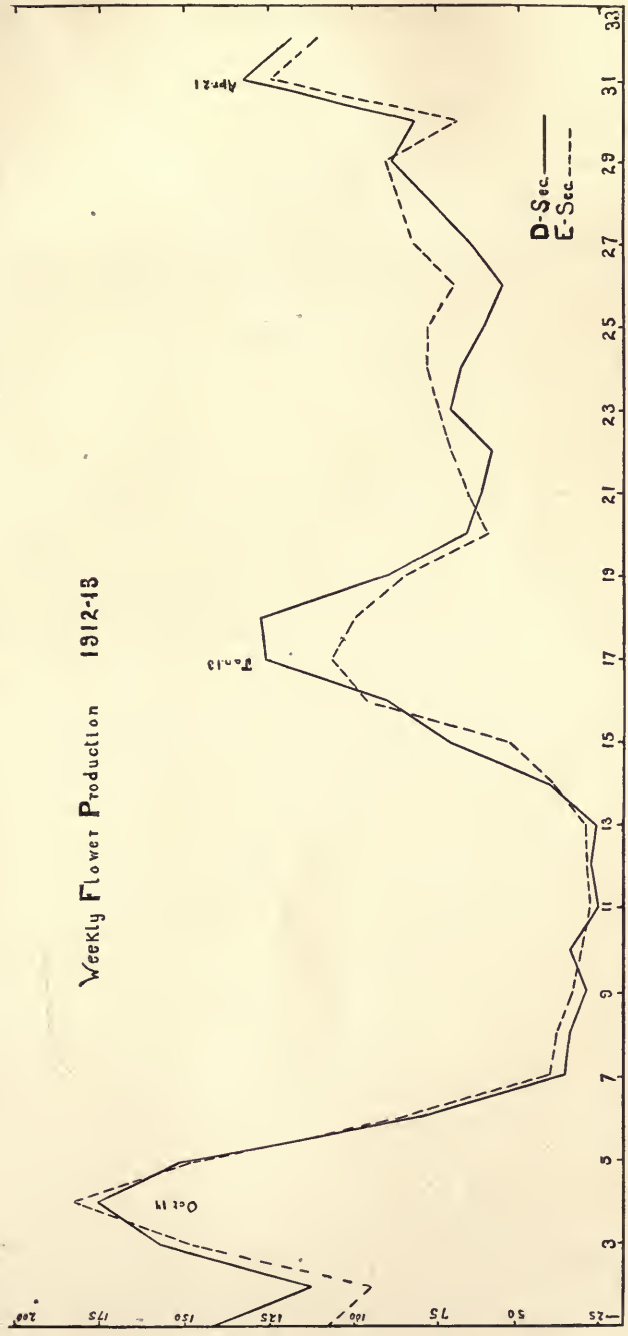


FIG. 1.—WEEKLY FLOWER PRODUCTION OF D AND E SECTIONS OF WHITE ENCHANTRESS, 1912-13

D-Sections—Manure
E-Sections—Commercial Fertilizers

| | 1909-10 | 1910-11 | 1911-12 |
|---|---|---|---|
| Dried blood per 100 sq. ft. ..... | 4 lbs. | 8 lbs. | 16 lbs. |
| Number of flowers per 24 plants ..... | 354.7 | 368.8 | 372.3 |
| Sulfate of ammonia per 100 sq. ft..... | 3 lbs. | 6 lbs. | 12 lbs. |
| Number of flowers per 24 plants ..... | 360.4 | 361.6 | 374.8 |

These figures are as nearly the same as could be expected. The quality of the flowers, judged in the usual manner, was about the same in both cases.

The production of flowers in a similar experiment in which acid phosphate and rock phosphate were used as sources of phosphorus was as follows:

| | 1909-10 | 1910-11 | 1911-12 |
|---|---|---|---|
| Acid phosphate per 100 sq. ft. ..... | 1 lb. | 2 lbs. | 4 lbs. |
| Number of flowers per 24 plants ..... | 367.8 | 357.5 | 368.3 |
| Rock phosphate per 100 sq. ft. ..... | 4 lbs. | 8 lbs. | 16 lbs. |
| Number of flowers per 24 plants ..... | 342.7 | 364.2 | 363.2 |

Neither the results from increasing the acid phosphate nor from increasing the rock phosphate showed any consistent variation. As stated previously (page 371), these inconsistencies might not have appeared if an ample amount of dried blood had been present. Until this point is settled by experiment, nothing can be determined in regard to the relative value of the two materials supplying phosphorus.

## EFFECT OF LARGE AMOUNTS OF ACID PHOSPHATE

The effect of applying large amounts of acid phosphate was tested during the year 1912-13 with White Perfection and Enchantress. To one section of each variety there were applied weekly about 2¾ pounds of acid phosphate per 100 square feet of bench space, and during the season, 8 pounds of dried blood (twice the amount applied in the experiment with acid and rock phosphate just considered) and 2 pounds of potassium sulfate. The "check" section was treated with like amounts of dried blood and potassium sulfate and a single application of 2 pounds of acid phosphate. In each section 40 plants were grown. The results are given in Table 10.

These results, obtained from one year's experiment, mean that on the same basis 100 plants of Enchantress would produce 225 more flowers by these additional applications of acid phosphate. At the average value of carnations, say $3 per hundred (the flowers in this section were of the very best quality), these additional blossoms would return a gross profit of $6.75. As the cost of enough acid phosphate to treat 100 plants in this way (at $15 per ton) is 56 cents, the net profit would be $6.19, or 1,000 percent profit on the investment (the cost of labor is negligible in comparison with the percentage of profit). With White Perfection the gross profit per 100 plants producing at the increased rate would be $2.25, the net profit $1.69, or 200 percent on the investment.

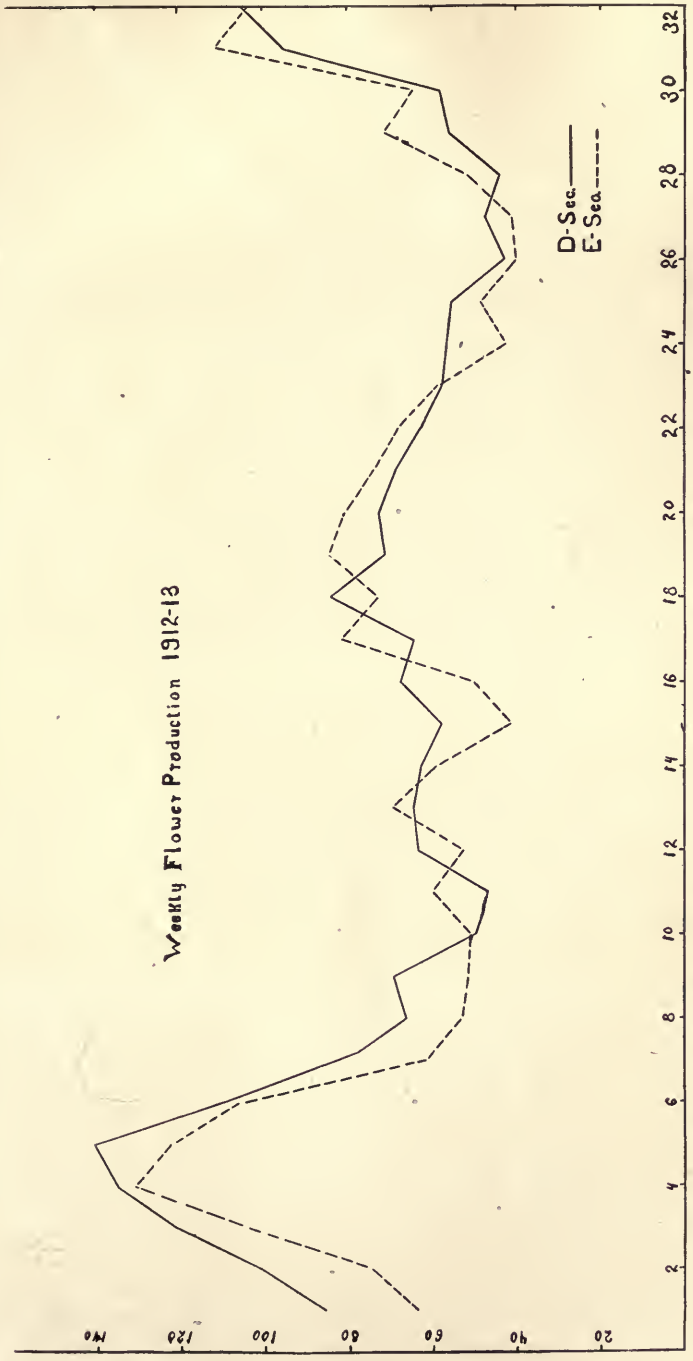


FIG. 2.—WEEKLY FLOWER PRODUCTION OF D AND E SECTIONS OF WHITE PERFECTION, 1912-13

D-Sections—Manure
E-Sections—Commercial Fertilizer

TABLE 10.—EFFECT OF LARGE AMOUNTS OF ACID PHOSPHATE ON NUMBER AND QUALITY OF FLOWERS

| Treatment | Flowers | Perfect calyces | Size | Length of stem |
|---|---|---|---|---|
| White Perfection | | | | |
| | *No.* | *percent* | *inches* | *inches* |
| "Check" | 597 | 86.5 | 2.91 | 14.39 |
| Large amount of acid phosphate | 628 | 89.0 | 2.95 | 13.78 |
| Difference | 31 | ... | ... | .... |
| Enchantress | | | | |
| "Check" | 678 | 82.1 | 3.18 | 14.55 |
| Large amount of acid phosphate | 768 | 86.8 | 3.19 | 14.42 |
| Difference | 90 | ... | ... | .... |

The flowers grown in the heavily fertilized sections were of excellent quality. How they compared with those from the check sections is shown in Table 10.

The stems of the plants in the phosphate sections were noticeable for their brittleness, both at the nodes and between; they were remarkably rigid and had a large diameter. It is possible in this case that the brittleness was due to the deficiency of potash in the fertilizer in comparison with nitrogen and phosphorus, rather than to the large amount of phosphorus.

## DANGER FROM OVERFEEDING

In contrast with the results obtained from heavy fertiiization with acid phosphate, marked injury resulted from like heavy applications of dried blood and potassium sulfate. Two sections, one of White Perfection and one of Enchantress, containing 40 plants each, were each treated weekly with 2¾ pounds of dried blood per 100 square feet of bench space. Two similar sections were each treated with 2¾ pounds of potassium sulfate weekly. To each of these four sections an application of 8 pounds of dried blood, 2 pounds of acid phosphate, and 2 pounds of potassium sulfate per 100 square feet was made in the fall. The check sections were the same sections described under the preceding heading. They received only 8 pounds of dried blood, 2 pounds of acid phosphate, and 2 pounds potassium sulfate during the year. The first application was made on October 4 and the last on April 25.

No harmful results were noted before about the first of the year. On December 16 the various sections had produced flowers in the numbers shown in Table 12.

A noticeably larger number of flowers had been produced in the sections fed with an excess of dried blood than in the check sections. About January 13, however, the first sign of overfeeding in both treatments was noticed, when the petals began browning at the edges, the center of the blossoms did not open, and many buds remained

TABLE 12.—EFFECT OF EARLY STAGES OF OVERFEEDING ON NUMBER OF FLOWERS

| Treatment | Flowers |
|---|---|
| White Perfection | |
| | *No.* |
| Excess dried blood | 264 |
| Excess sulfate of potash | 238 |
| "Check" | 219 |
| Enchantress | |
| Excess dried blood | 242 |
| Excess sulfate of potash | 209 |
| "Check" | 218 |

closed. In two weeks the flowers were ruined, hardly a salable blossom being present. The plants overfed with dried blood later recovered, but those overfed with potassium sulfate were ruined for the season.

The point to emphasize in regard to injury by overfeeding with dried blood or potassium sulfate is that *the first sign is on the petals themselves;* consequently the flowers are ruined when the overfeeding is discovered. The way to avoid overfeeding is to follow directions strictly as to the amount of fertilizer to apply, and to see that the fertilizer is weighed out. It must be remembered that "where a little is good, more is better" is not applicable to the use of fertilizers in the greenhouse.

## SYMPTOMS OF OVERFEEDING

The later stages of injury due to dried blood and potassium sulfate are quite characteristic for each fertilizer. As has been stated above, acid phosphate applied in large quantities produced no injury.

Flowers from plants overfed with dried blood become quite soft, and if watered overhead during sunshine, will show brown spots on the petals where a drop of water has stood. A little later the flowers are characterized by a peculiar bunching of the center petals, leaving only a double row or so of petals open as in normal condition. Later buds do not open, the flowers remaining stationary after the petals have shown a half-inch above the calyx. The foliage assumes a deep green color, with abundant "bloom," and growth is normal for a time. Continued feeding, however, causes a retardation in growth. Carnation plants overfed with dried blood will gradually recover.

The injury from equal applications of potassium sulfate is more pronounced and more persistent. The first sign of injury is a crinkling of the edges of the inner petals, some brown spots appear, and at times the edges of the petals are withered. This stage is followed by a stage in which the center petals fail to open, being glued by a syrupy secretion. For this reason the later buds never open. An interesting abnormality is found in buds thus swelled beyond normal diameter and not opened, yet with the pistil projecting an inch beyond the bud. In addition to the effect upon the flowers, the injury from potassium

sulfate is manifested by a marked retardation in the growth of the plant. The leaf tips gradually die, but the leaves altho somewhat thinner than normal develop to a nearly normal width and length. The internodes of developing shoots, however, seem to lose their power of elongation, and this, coupled with the nearly normal length of the leaves, combines to produce a "rosette" structure (see Fig. 3).

FIG. 3.—"ROSETTE" FORMATION OF CARNATION DUE TO OVERFEEDING WITH POTASSIUM SULFATE

## CONCLUSIONS

Experimental work of a character extensive enough to produce conclusive results has established the facts that dried blood (or in its place ammonium sulfate), acid phosphate, and potassium sulfate may safely be used in the culture of carnations. On the brown silt loam of the corn-belt area of Illinois, nitrogenous fertilizers have produced a consistent increase in production, and nitrogen may be regarded as the limiting element of growth. There are indications that acid phosphate (supplying phosphorus), if used with a nitrogenous fertilizer, will cause a still further increase in production and an improvement in quality as well.

The quality of flowers produced by culture with commercial fertilizers, as measured by size of flower, length of stem, percentage with perfect calyces, keeping power and strength of stem, is equal to that of those grown with manure.

The time of maximum crop production is independent of the kind of fertilizer applied and the time of its application.

Injury from overfeeding results from the excessive use of potassium sulfate and dried blood. The use of large quantities of acid phosphate, however, seems to improve the quality of the flowers and to increase their number.

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